Miami-Dade County Department of Solid Waste Management

State of the Waste Processing Technology Industry

Final Report

June 2022

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Acronyms and Abbreviations

APC	Air pollution control
B&W	Babcock and Wilcox
CCS	Carbon capture and sequestration
Cd	Cadmium
CO	Carbon Monoxide
County	Miami-Dade County
Covanta	Covanta Energy Corporation
CSWSP	CT Solid Waste System Project
CT	Connecticut
CSWS RRF	Connecticut Solid Waste System Resource Recovery Facility
CTDEEP	Connecticut Department of Energy and Environmental Protection
DSWM	Department of Solid Waste Management or Department
FDEP	Florida Department of Environmental Protection
FOG	Fats, Oils and Greases
G3P	Green3Power St. Lucie, LLC
GHG	greenhouse gas
GWP	global warming potential
HAPs	hazardous air pollutants
HCl	Hydrogen Chloride
Hg	Mercury
JSE	Jacoby Synergy Renewables
LAER	lowest achievable emissions rate
MACT	maximum achievable control technology
MBT	Mechanical Biological Treatment
MIRA	Materials Innovation Recycling Authority
MSW	Municipal Solid Waste
MTCE	metric tons of carbon equivalent
MTCO2E	metric tons of carbon dioxide equivalent
MWCs	Municipal Waste Combustors

NESHAPs	National Emission Standards for Hazardous Air Pollutants
NH3	Ammonia
NOx	Nitrogen Oxides
NSPS	New Source Performance Standards
Pb	Lead
PBF	Power Block Facility
PEF	processed engineered fuel
PM	Particulate Matter
RDF	Refuse-derived fuel
RFQ	Request for Qualifications
RFI	Request for Information
RFP	Request for Proposals
RNG	renewable natural gas
RRA	Resource Recovery Act
SCR	Selective Catalytic Reduction
SIP	state implementation plan
SNCR	Selective Non-Catalytic Reduction
SO2	Sulfur Dioxide
SOI	State of the Industry
SWA	Solid Waste Authority of Palm Beach County, Fl
TCLP	Toxicity Characteristic Leaching Procedure
TPD or tpd	Tons per day
US or USA	United States of America
USEPA	United States Environmental Protection Agency
USPHS	US Public Health Service
WARM	Waste Reduction Model
WPF	Waste Processing Facility
WTE	Waste-to-Energy

1 Introduction and Background

The purpose of this state of the industry (SOI) report is to provide Miami-Dade County (County) Department of Solid Waste Management (DSWM or Department) a summary of the latest commercially-available processing technologies used in the solid waste industry that may be suitable for handling the County's municipal solid waste stream. This report will review the history of waste to energy (WTE) facilities in the solid waste industry, environmental characteristics of WTE and waste processing facilities, proven waste processing technologies at a commercial scale, emerging waste processing technologies, recent procurements of WTE facilities and recommendations of waste technologies to be used by the County. The information presented in this report is based on data and information that is available from published sources and vendor information and is augmented by general industry experience. Specific vendors for each general technology type are not reviewed in detail in this report.

The County requires a new waste processing or disposal facility to replace an existing WTE facility that, without significant refurbishment, is approaching the end of its useful life. The County's landfills are nearing capacity in the next few decades and transporting the County's waste to central Florida landfills has been determined by the County to be inefficient, unsustainable, and not resilient. The County plans to issue a Request for Information (RFI) to obtain information to determine the current best practices, industry standards, available technologies, supplier availability, vendor capabilities and interest, supplier recommendations for a successful project and location, and input on the procurement process for a new WTE facility. The new WTE facility is anticipated to have a throughput capacity of 4,000 tons per day (tpd) of municipal solid waste (MSW) with a possible future expansion capability of up to 5,000 tpd of MSW.

This SOI report will provide the County additional background information regarding the solid waste processing industry to assist the County when reviewing responses to the RFI as well as when considering technology options for the potential new WTE facility. It is important to note that this report only provides information that is publicly and readily available at the time of issuance of this report, and the County should be aware that responses to the RFI may include additional waste technologies and specific technology suppliers that were not discussed in this SOI report. Additionally, overviews of technologies reviewed are limited to (a) technologies that are capable of processing municipal solid waste (MSW) or portions of the MSW stream on a commercial basis (demonstrated technologies) or (b) technologies that are reported to be developing the capability to become commercially viable for processing MSW (emerging technologies). Both demonstrated and emerging technologies are included to provide an appropriate perspective of the range of potential alternatives that may be available.

As the County has already evaluated recycling and waste diversion technologies[1], the focus of this SOI report is on processing and disposal technologies that process municipal solid waste, after residential and commercial recycling and diversion efforts, commonly referred to as post-recycled MSW. The evaluated technologies must provide some type of volume or weight reduction to reduce impact to both the County's existing landfills and disposal options at other private landfills within the region or state. As an example, this report may include technologies that can only process certain subsections of MSW, such as: woody waste or yard waste, food waste and other organics, refined or processed MSW to remove non-combustibles also referred to as refuse-derived fuel (RDF), and technologies that focus on the entire remaining post-recycled MSW stream such as mass-burn.

1 Refer to Board Memo, dated February 11, 2022, summarizing efforts related to evaluating options for Countywide recycling (Directive 192055) and the "Recycling Analysis and Program Planning" report, dated July 2021.

2 WTE Historical Perspective

The first solid waste incinerator facility or waste to energy (WTE) facility in the United States that combusted municipal solid waste (MSW) was constructed in New York in 1885. The use of incineration grew during the early decades of the 20th century until the 1930s, when there were more than 700 units in operation.

In the early 1960s the US Public Health Service (USPHS) solid waste program began to study problems with incineration as a means of disposal. At that time, many major US cities depended on those antiquated, poorly designed, and operated WTE facilities to manage a major portion of their waste disposal. With the assistance of USPHS, the industry began to develop new concepts in design, materials, and operation. New designs included the installation of scales to help monitor and control the waste feed throughput of the facility, and larger tipping floors and pits designed to handle the volume of the facilities. Hoppers were designed to allow gravity flow of MSW into furnaces and to provide a seal at the charging end of the unit. Bridge cranes became the main means for charging furnace hoppers, while terminology became more standard with design terms. Several advancements in air pollution control technology and improved combustion practices continued.

In 1970, the Resource Recovery Act (RRA) amended the federal solid waste legislation and developed a broader solid waste role for the federal government. RRA defined resource recovery as the recovery of both materials and energy recovery from MSW. Many old incinerators were shut down due to pressures of the Clean Air Act as well as the emergence of sanitary landfills. The RRA gave federal solid waste program opportunities to address WTE with financial and staffing resources and to expand the efforts that began during the 1960's to enhance and increase the efficiencies of WTE facilities. Throughout the 1970's and 1980's federal solid waste programs studied many new MSW combustion concepts, specifically, ones that would allow for the recovery of both materials and energy.[2]

In accordance with the United States Environmental Protection Agency (USEPA) data from 2020 as updated for the Bay County, FL WTE Facility closure in 2021[3], there are 73 WTE facilities in operation in the United States, 57 of those facilities use mass burn technologies, 12 facilities use RDF technologies, and four facilities used modular technologies (a type of mass burn technology).[4] In July 2015, the Solid Waste Authority of Palm Beach County achieved commercial operations of the 3,000 tpd Palm Beach Renewable Energy Facility No. 2, which was the last new WTE facility constructed in the United States.

3 Environmental Characteristics of Waste Processing Technologies

3.1 Air Quality Regulations

The purpose of this section is to discuss the regulations related to solid waste combustion facilities that are expected to include WTE, RDF, pyrolysis and gasification facilities except for certain technologies related that

2 https://www.mswmanagement.com/collection/article/13001185/a-brief-history-of-solid-waste-management-during-the-last-50-years-part-9a

3 https://www.wastedive.com/news/florida-incinerator-bay-county-shutting-down-wte/584718/#:~:text=The%20Bay%20County%20Waste-to-Energy%20Facility%20operated%20by%20Engen,vote%20by%20county%20commissioners%20to%20wind%20down%20operations.

4 "Assessment of Municipal Solid Waste Energy Recovery Technologies – Final Report", dated December 2020, prepared for the USEPA.

may be dependent on how the fuel is used to generate the power such as anaerobic digestion. Solid waste combustion facilities, commonly referred to as incinerators, which the EPA refers to as Municipal Waste Combustors (MWCs), are regulated under the federal Clean Air Act, originally passed by Congress in 1963, and amended in 1990. The Clean Air Act directs EPA to establish pollution control requirements for criteria air pollutants, which are known as the New Source Performance Standards (NSPS). The NSPS includes limits on emissions from new, modified, and reconstructed MWCs. In 2015, the EPA issued final regulations to also limit greenhouse gas (GHG) emissions from new sources[5]. For facilities performing thermal destruction of solid waste, the NSPS include limits for sulfur dioxide (SO2), carbon monoxide (CO), nitrogen oxides (NOx), hydrogen chloride (HCl), dioxins/furans, particulate matter (PM), cadmium, lead, mercury, fugitive ash, and opacity. NSPS regulations are detailed in Chapter 40 of the Code of Federal Regulations, Part 60 (40 CFR 60), and are intended primarily to establish minimum nationwide requirements for new and existing MWCs (under 40 CFR 60 Subpart Eb for new MWCs and 40 CFR 60 Subpart Cb for existing MWCs).

The Clean Air Act also regulates hazardous air pollutants (HAPs). These pollutants include asbestos, benzene, beryllium, inorganic arsenic, mercury, radionuclides, and vinyl chloride. National emission standards for hazardous air pollutants (NESHAPs) are detailed in 40 CFR Part 61 and establish minimum nationwide requirements for existing and new facilities. NESHAPs require an evaluation of the maximum achievable control technology (MACT) for controlling HAPs and are often referred to as "MACT standards". NESHAP regulations can be found in 40 CFR Part 63 and establish nationwide requirements for existing and new facilities.

Under the Clean Air Act sections, the EPA may implement and enforce the requirements of these standards or may delegate such authority to state, local, or tribal regulatory agencies. For the purposes of a facility within Miami-Dade County, the EPA would delegate permitting actions and enforcement authority to the Florida Department of Environmental Protection (FDEP). This delegation is typically limited to allowing the FDEP to draft specific rules for managing permits and monitoring emissions, including potentially making more stringent regulatory requirements, but does not allow the FDEP any authority to lower requirements to below the minimum federal regulatory standards. The Clean Air Act emissions limits applicable to new MWCs are shown below:

Table 3-1. Clean Air Act Emission Limits

Air Pollutant	Emissions Limit[1,2]
Cadmium (Cd)	10 µg/dscm
Carbon Monoxide (CO)	100 ppmvd
Dioxin/furan (Total Mass Basis)	13 ng/dscm
Fugitive Ash	Visible emissions for no more than 5 percent of the hourly observation period
Opacity	10 %
Hydrogen Chloride (HCl)	25 ppmvd
Lead (Pb)	140 µg/dscm

5 https://www.epa.gov/stationary-sources-air-pollution/nsps-ghg-emissions-new-modified-and-reconstructed-electric-utility

Air Pollutant	Emissions Limit[1,2]
Mercury (Hg)	50 µg/dscm
Nitrogen Oxides (NOx)	150 ppmvd
Particulate Matter (PM)	20 mg/dscm
Sulfur Dioxide (SO_2)	30 ppmvd

Notes:
1. Emission limits reflect the NSPS for new MWCs (40 CFR 60 Subpart Eb).
2. All concentrations are corrected to 7% O_2.

Air permitting for a WTE facility can be a lengthy process and requires a multitude of analysis and correspondence with a variety of regulatory agencies. Any new WTE facility would be considered a new major source of air pollutant emissions and be required to obtain a Prevention of Significant Deterioration (PSD) permit under the New Source Review (NSR) permitting program. The PSD permitting process is complex, includes public participation, and requires completion of various air quality analyses. These analyses include BACT analyses for the air pollutants associated with the planned emission units, dispersion modeling analyses to determine air quality impacts at nearby receptors and at receptor locations within federally protected Class I areas, visibility analyses to determine impacts at the Class I areas, and a toxic air contaminant impact analysis. Prior to issuance of a final air construction permit, multiple iterations of these analyses will likely be required to address any adverse impacts and to satisfy concerns of the permitting authorities, Federal Land Managers responsible for the Class I areas, and the public. As the Everglades National Park is a designated Class I area and close to any location within Miami-Dade County, this process could be lengthy for any new facility within the County.

All sources at the facility must comply with applicable federal standards mentioned above. These regulations prescribe emission standards as shown in the table above, require monitoring and performance testing, and include siting requirements. The siting requirements specify that a detailed Materials Separation Plan be completed (preliminary and final draft versions) with a defined public review process.

As a major source, the Facility will also be required to obtain a Title V operating permit. A Title V permit application can be submitted after the PSD construction permit is issued or concurrently with the PSD construction permit application. Considering the complexities associated with the Facility and anticipated construction schedule, it is recommended to prepare and submit the Title V permit application after the PSD construction permit is issued. The southeast Florida airshed, Broward, Miami-Dade and Palm Beach Counties, were previously a non-attainment area for ozone, which would have imposed additional permitting requirements on the facility. However, at the time of this SOI report, that status is currently revoked. If this revocation reverses before the attempt to permit a new facility, any new facility (new source) will be required to adhere to the lowest achievable emissions rate (LAER). This will be the lowest emissions rate achieved by a similar source or the lowest rate for a similar source in a state implementation plan (SIP) anywhere in the country. The two pollutants impacted by this are oxides of nitrogen (NOx) and volatile organic compounds (VOC). These analyses would raise the development cost and increase the time required to go through the permit process for a waste conversion facility. The most common control technology for NOx, Selective Non-Catalytic Reduction (SNCR), can reduce emissions to 100 ppm, below required limits. Additional reduction in NOx is achieved by urea or ammonia injection into the furnace. The only recently permitted MWC for a new source in Florida in the last twenty (20) years was the Palm Beach Renewable Energy Facility No. 2 (PBREF No. 2) in Palm Beach County, which became commercially operable in 2015. Permitting efforts for that facility were required by the FDEP to include Selective Catalytic Reduction (SCR) technology for NOx reduction, so it is likely that any facility in Miami-Dade would be required to be at least as stringent as that facility from a permitting perspective. The initial permit limits for the PBREF No. 2 facility are listed below for reference in Table 3-2. Table 3-3 shows the permit limit and recent stack testing results to demonstrate the ability to operate below such limits.

Table 3-2. Initial Permit Limits

Pollutant	Emission Standard/Limit[1]	lb/hour[3]	Basis
NOx	50 ppmvd – 24-hour block arithmetic mean	37.4	BACT
	45 ppmvd – 12-month rolling average		BACT
CO	100 ppmvd – 4-hr block arithmetic mean	45.5	Subpart Eb
	80 ppmvd – 30-day rolling average		BACT
SO2	24 ppmvd – 24-hour geometric mean	25.0	BACT
HCl[3]	20 ppmvd	11.9	BACT
VOC (as propane)	7 ppmvd	5.0	BACT
$PM/PM_{10}/PM_{2.5}$ (filterable)	12.0 mg/dscm	4.7	BACT
Lead (Pb)	125 µg/dscm	0.049	Avoid PSD
Hg[4]	N/A[5]	37.7 lb/yr[6]	Avoid PSD
	25 µg/dscm	0.0098	Applicant Request
Cadmium (Cd)	10 µg/dscm	3.91E-03	Subpart Eb
Dioxins/Furans[7]	13.0 ng/dscm		Subpart Eb
	10 ng/dscm during initial two years		Initial Test
	0.75 to 10 ng/dscm 3rd year and thereafter		BACT
Opacity	10% - 6-minute average	N/A[5]	BACT
Ammonia Slip	10 ppmvd	2.76	PM, Opacity

Notes:

1. All concentration values are corrected to 7% O2: µg/dscm = micrograms per dry standard cubic meter; mg/dscm = milligrams per dry standard cubic meter; ng/dscm = nanograms per dry standard cubic meter; and ppmvd = part per million dry volume.
2. Mass emission limits reflect maximum values calculated at 110% of 24 hours steam production limit of 291,000 lb steam/hr for each MWC. The 110% steam limit is 320,100 lb steam/hr for each MWC.
3. HCl is not a BACT pollutant. However, it must be limited together with SO2 because they both comprise MWC-Acid Gases which has its own PSD threshold.
4. Within 60 days after achieving the maximum production rate, but not later than 180 days after the initial startup, PBREF No. 2 shall commence quarterly performance Hg stack test events for each MWC exhaust flue to show compliance with the 25

Pollutant	Emission Standard/Limit[1]	lb/hour[3]	Basis

µg/dscm emission limit. The 25 µg/dscm quarterly stack-based standard is based on the applicant's request. By meeting the quarterly stack test standard, PBREF No. 2 will show compliance with Subpart Eb Hg emission standard of 50 µg/dscm.

5. N/A = not applicable
6. The 37.7 lb/yr emission limit is a 12-month rolled monthly average based on CEMS data. The Hg CEMS must become operational within 60 days after PBREF No. 2 achieves its maximum production rate, but not later than 180 days after the initial startup. During the first four quarters of Hg CEMS availability, the CEMS must achieve an 80% data availability rate. Subsequently, an 85% data availability rate is required.
7. Dioxins/furans: Total tetra through octa-chlorinated dibenzo-p-dioxins and dibenzofurans. During the first year of the PBREF No. 2 operation of the 10 ng/dscm limit applies. Subsequently, the To Be Determined (TBD) limit will govern based on initial performance and efficiency tests at the inlet and outlet of the SCR.

Table 3-3. Example Permit Limits and Emissions from PBREF No. 2

Sample Type	Limit	Units[1]	Test Result [6]		
			Unit #3	Unit #4	Unit #5
Ammonia Slip (NH3)	10	ppmvd[3]	2.59	5.01	2.40
	2.76	lb / hr	0.78	1.58	0.77
Particulate Matter (PM) (filterable)	12	mg / dscm[2]	1.93	3.04	2.59
	4.7	lb / hr	0.82	1.32	1.16
Hydrogen Chloride (HCl)	20	ppmvd[3]	6.18	6.78	4.19
	11.9	lb / hr	3.99	4.43	2.85
Volatile Organic Compounds (VOC) (as propane)	7	ppmvd[3]	0.96	0.26	0.18
	5.0	lb / hr	0.74	0.21	0.15
Lead (Pb)	125	µg / dscm[2]	1.20	8.32	1.29
	4.9 E-02	lb / hr	5.14E-04	3.55E-03	5.64E-04
Cadmium (Cd)	10	µg / dscm[2]	<0.50	1.86	0.43
	3.91 E-03	lb / hr	<2.10E-04	7.97E-04	1.88E-04
Mercury (Hg)	25	µg / dscm[2]	<0.67	0.72	1.10
	9.8 E-03	lb / hr	<2.89E-04	3.08E-04	4.81E-04
Outlet Dioxins / Furans[5]	4.2	ng / dscm[4]	0.67	0.21	0.44

Sample Type	Limit	Units[1]	Test Result [6]		
			Unit #3	Unit #4	Unit #5
Visible Emissions	10	%	0.0	0.0	0.00
Carbon Monoxide	100	ppmvd[3]	31.9	15.5	13.6
	45.5	lb / hr	8.74	6.51	5.64
Nitrogen Oxides	50	ppmvd[3]	36.7	39.9	37.6
	37.4	lb / hr	30.1	26.2	26.3
Sulfur Dioxide	24	ppmvd[3]	20.3	20.7	21.4
	25.0	lb / hr	19.4	20.3	19.9
Opacity	10	%	0.9	2.1	0.8

Notes:
1. All concentrations are corrected to 7% O_2.
2. Micrograms per cubic meter on a dry basis at standard conditions.
3. Parts per million on a dry volume basis.
4. Nanograms per cubic meter on a dry basis at standard conditions.
5. Based on stack testing performed over the first two full years of commercial operation, the dioxin/furan emission limit was set to 4.2 ng/dscm @ 7% O_2, which is equivalent to 1.7×10^{-6} lb/hr.
6. Testing results are from the March 2018 stack testing program.

3.2 Greenhouse Gases

Combustion of MSW in a WTE facility results in the emissions of carbon dioxide (CO_2) and nitrous oxide (N_2O). Carbon dioxide is the most significant GHG emitted by WTE. Nitrous oxide is produced at much lower concentrations in a WTE facility compared to CO_2, but is a more potent GHG with a global warming potential (GWP) 298 times that of CO_2. Carbon dioxide from WTE is primarily emitted as a product of combustion and from transporting the residual waste ash to a landfill. Furthermore, GHG emissions (primarily CO_2) would be generated from WTE facility construction activities (e.g., worker transportation, truck delivery of supplies, raw materials, etc.) and from operations of the WTE facility (e.g., truck deliveries of supplies, worker transportation, etc.).

Construction and miscellaneous operational-GHG emissions (e.g., raw materials, delivery of supplies, worker commute) from a WTE facility are currently difficult to estimate. However, GHG emissions associated with these activities should be a relatively small component of the overall lifetime GHG emissions considering the long-term duration of a WTE facility.

The U.S. EPA has developed a Waste Reduction Model (WARM) to help solid waste planners and organizations estimate greenhouse gas emission reductions from several different waste management practices. WARM calculates GHG emissions for baseline and alternative waste management practices, including source reduction, recycling, combustion, composting, and landfilling. The model calculates emissions in metric tons of carbon equivalent (MTCE) and metric tons of carbon dioxide equivalent (MTCO2E) across a wide range of material types commonly found in municipal solid waste (MSW). In addition, the model calculates energy use for each of the options. This tool could be used by Miami-Dade to estimate the amount of greenhouse gas emissions from a new WTE facility and how it would compare to alternative MSW management approaches. WARM models require data inputs related to waste generation, waste characterization, and recycling rates in addition to waste management/disposal alternatives.

Arcadis performed a recent WARM analysis for King County, Washington as part of a comparison of a new WTE facility of similar size to the proposed facility for Miami-Dade County vs rail (and truck) hauling and ultimate landfilling of MSW as shown in Tables 3-4 and 3-5 below, respectively.

Table 3-4. GHG Results for WTE using Method 2 in King County, WA for a 4,000 TPD WTE facility

Description	MTCO2E/ton[1]
CO2 and N2O from MSW Combustion[2]	0.42
Truck transport of ash from WTE to IMF	0.008
Rail transport of ash from IMF to landfill	0.002
Avoided Utilities - Washington	-0.26
Avoided emissions – steel recovery	-0.04
Avoided emissions – AMP	-0.11
Avoided emissions – ash recycling	-0.07
Total	-0.05

Notes:

1. MTCO2E/ton = metric tons of carbon dioxide equivalent per short ton of MSW
2. The gross GHG emissions from MSW Combustion are based on national average values which include older WTE technologies. The GHG emissions from a new WTE facility would presumably be less due to advances in combustion technology. Additionally, the percentage of plastics in MSW is reportedly higher nationally than in King County (e.g., 18.3% versus 12.2%, suggesting that the WTE GHG emissions for the King County waste composition may be less than national averages).

Table 3-5. GHG Evaluation for Disposal of MSW at Out-Of-County Landfill in King County, WA

Description	MTCO2E/ton[1]
Methane not captured by LFG recovery[2]	0.32
Landfill equipment operation	0.02
Rail transport of ash from IMF to landfill	0.03
Avoided Utilities - Washington	-0.08
Avoided emissions – carbon sequestration	-0.21

Description	MTCO2E/ton[1]
Total	0.08 – 0.29

Notes:

1. Methane not captured by LFG recovery system assumes methane generation from anaerobic generation is 1.62MTCO2E per ton of MSW and 80% LFG recovery. The 80% is based on professional judgment and EPA efficiency testing performed in 2012 and assumes aggressive landfill gas capture.
2. MTCO2E/ton = metric tons of carbon dioxide equivalent per short ton of MSW

While these comparisons are not a perfect comparison for Miami-Dade County based on transportation and hauling differences and potential waste composition differences, the waste tonnages under consideration are similar and the analysis does illustrate an overall net reduction in GHG based on WTE compared to landfilling with aggressive landfill gas capture and re-use.

At the time of this report, there is no large-scale commercial success of carbon dioxide capture and sequestration out of WTE flue gas. However, carbon capture and sequestration (CCS) technologies are currently being explored and tested at multiple WTE facilities outside of the United States. While this technology may not be fully commercial at the inception of any new facility by Miami-Dade County, the technology is on the cusp of commercial viability and may become sufficiently commercial to include during the design and inception process.[6]

3.3 Water

Mass-burn and RDF combustion technologies utilize water in order to generate steam to rotate the turbine and produce electricity as well as for standard potable uses. Water is also a key necessary resource for facility process functions such as cooling functions on heat exchangers and desuperheaters, quenching bottom ash after combustion, and mixing with air pollution control chemicals for air pollution control usage. While detailed engineering can occur to clean and re-use existing internal water sources in an attempt to create a “zero-discharge” facility during normal operations, generally all types of WTE facilities have a wastewater discharge or the ability to discharge wastewater during atypical operating periods.

Non-potable water may also be used as cooling water for the steam condensers, but the large cooling water supplies necessary for condenser cooling are normally not available, and cooling towers or cooling water ponds are often provided as part of the facility. However, due to water availability and restrictions, it has become more common on construction of recent WTE facilities to utilize air-cooled condensers to lower overall water usage requirements. Air cooled condensers increase the internal electrical demand and reduce net exports to the grid, which can be balanced against water use restrictions or space availability for ponds or other source restrictions.

It is also common in Europe and in northern portions of the United States for some projects to cogenerate steam and electricity for sale, such as district heating/cooling projects or those with a significant steam user in proximity of the WTE facility site.

Other technologies such as gasification and anaerobic digestion will not necessarily use a boiler and do not typically require a large condenser for cooling. However, they would still typically require potable water use, as well as have internal process requirements for cooling water and air pollution control.

6 https://www.globalccsinstitute.com/wp-content/uploads/2019/10/Waste-to-energy-with-CCS_A-pathway-to-carbon-negative-power-generation_Oct2019-4.pdf

3.4 Residue Disposal

Ash will be generated by non-high temperature thermal waste options such as mass-burn combustion, RDF combustion, gasification and pyrolysis. In 2016, United States WTE facilities generated approximately seven million tons of ash, which can be categorized as either bottom ash or fly ash. Bottom ash is the material that is either falls through a furnace grate or remains on the grate after the waste is combusted. Bottom ash also includes heat recovery ash that is collected in the heat recovery system of the facility. Fly ash refers to ash that becomes entrained in flue gas that is collected by an air pollution system. The bottom ash/fly ash split is approximately 15% fly ash by weight compared to 85% bottom ash by weight, but can vary based on the combustion technology and waste composition. [7] Bottom ash typically represents a 75% reduction by weight of the MSW processed by WTE facilities and is typically a reduction in volume of 90%. Bottom ash is typically not classified as a hazardous material, subject to ash testing and analysis. Fly ash, however, when collected separately, will have a higher concentration of heavy metals. Fly ash is typically treated as a hazardous material unless it is combined with bottom ash, prior to testing, which is the current practice utilized at most United States WTE facilities. However, based on Arcadis' experience and observations, most recent testing of fly ash at WTE facilities in Florida has shown a downward trend in heavy metals concentrations (speculatively due to the changing waste composition and better recycling programs) and show that the ash is often not testing as hazardous. Laws and regulations, both by the EPA and the FDEP, require WTE operators to test this ash to ensure it is non-hazardous through a test called Toxicity Characteristic Leaching Procedure (TCLP). In Florida, this results in an initial characterization of the ash streams and requires further testing if any substantial changes occur in the average waste composition or processing or air pollution control equipment technology. If the fly ash is separated, often for purposes of increased metals recovery in the bottom ash and ash recycling efforts, it can be treated, if necessary, with a fixative to prevent leaching of hazardous constituents so it can be classified as non-hazardous.

WTE facilities are capable of recovering ferrous and non-ferrous metals in bottom ash from products and packaging discards that are not collected in source-separation recycling. There are two approaches that are being used on a commercial scale to recover these metals; wet ash dry processing systems and dry ash processing systems. Wet ash dry processing systems quench the bottom ash following combustion. Recovery is performed based on the particle size and density of the wet bottom ash. This is the system that is most common in United State WTE facilities. Dry ash processing systems do not quench bottom ash, but use air to cool the ash and use magnetic systems to recover metals.[8]

Florida regulations require applications for construction permits of WTE facilities to include an ash management plan. The plan must describe measures to control dispersion of ash residue and location of ash disposal. The plan must include ash quantity estimates and recycled material estimates.[9] WTE ash in Florida has typically been used as a cover for sanitary landfills. Other applications of ash have included landfill shaping and grading material, landfill gas venting layers, as well as construction and road fill applications. States may have different laws and regulations that limit how WTE ash can be applied.

In recent years, Florida has been on the forefront of additional post-recovery metals capture technologies to improve collection efforts and performing pilot testing of bottom and combined ash re-use projects. These efforts,

7 https://www.mswmanagement.com/home/article/13026561/innovations-in-wastetoenergy-ash-management

8 https://www.mswmanagement.com/home/article/13026561/innovations-in-wastetoenergy-ash-management

9 Florida Statutes, Chapter 62-702 Solid Waste Combustor Ash Management

in coordination and with the approval of the FDEP, have resulted in significant quantities of additional ferrous and non-ferrous metals removal, and successful ash re-use projects for roadway construction and testing for use as aggregate in concrete and asphalt mixes. Miami-Dade's current RDF processing facility currently performs post-recovery of metals on WTE ash from its facility as well as on ash from other facilities in the south Florida area and has been working with FDEP to test future ash re-use opportunities.

For gasification and plasma-arc technologies, inorganic materials such as metals and glass melt in the pyrolysis chamber and forms a gravel-like black substance called frit or obsidian that can be used as an aggregate for building roads or sold as a secondary product for other processes. Char is additionally produced and exits from the bottom chamber, where it can be processed for metals recovery. Typical residue percentage is greater than 10% by weight of incoming processed material.

For anaerobic digestion technologies, the organic substrate after the digestion process, digestate, may also be beneficially processed and recovered as a compost-like soil conditioner. The residue then remaining from anaerobic consists of stones, glass or similar items, which is normally directed to a solid waste landfill. If not beneficially processed, the residue quantity and characteristics are substantially similar to MSW with organic materials removed. Assuming all digestate is utilized as compost, the remaining residue is approximately 5% to 10% by weight of incoming processed material.

4 Proven Waste Processing Technologies

Municipal solid waste (MSW) consists of energy-rich material such as paper, plastics, yard wastes, and wood, and inorganics such as metals. Most large waste processing technologies in the United States primarily utilize post-recycled MSW, which is MSW that remains after typical residential and commercial recycling has occurred. For this reason, this report does not focus on certain specific technologies, such as chemical decomposition of paper and plastics or other gasification efforts for recyclable materials. Large-scale waste processing methods focused for inclusion in this report include the following:

1. Mass-Burn/Waterwall Combustion: This is the controlled combustion of post-recycled, unprocessed, mixed MSW. The furnace is constructed with water/steam tubes to efficiently capture energy. Waterwall systems are fabricated on-site and generally have larger unit sizes (200-1000 tpd) in the United States.[10]
2. Modular Technologies: Modular technologies typically burn unprocessed, mixed MSW and differ from mass burn facilities in that they are typically much smaller (5-140 tpd) and utilize standard sizes for construction. Modular technologies are often built off-site and hauled to site rather than built in place.[11]
3. Refuse-Derived Fuel (RDF)/Dedicated Boiler: This process uses mechanical methods to shred incoming MSW. The shredded MSW is then sorted and all non-combustible materials such as glass, metals, and stones under a certain size fraction are removed. A combustible mixture is produced that has a higher heating value than traditional mixed MSW and is utilized as fuel in a dedicated furnace or as a supplemental fuel in a conventional boiler system.[12]

It is important to note that there are other methods of MSW disposal practiced in the United States such as mixed-waste composting and landfills, however, neither of these technologies are focused on within this report due to

10 https://wasteadvantagemag.com/the-resurgence-of-waste-to-energy-and-conversion-technologies-wheres-the-risk/

11 https://www.epa.gov/smm/energy-recovery-combustion-municipal-solid-waste-msw

12 https://www.sciencedirect.com/topics/engineering/refuse-derived-fuel#:~:text=RDF%20is%20the%20product%20of%20the%20treatment%20of%20MSW%20to,as%20glass%2C%20metal%20and%20stone.

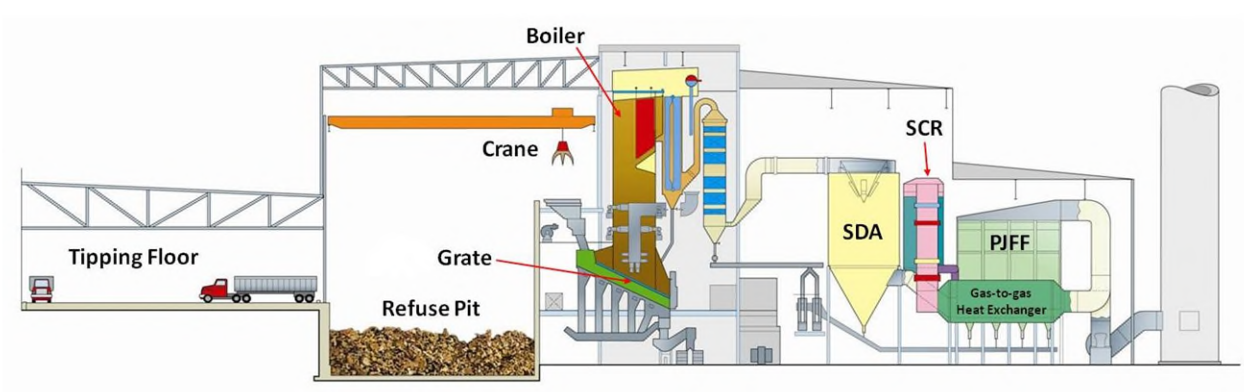
specific technical limitations in Miami-Dade County. Mixed-waste composting requires large land areas and/or high capital investment. It is typically difficult to site due to the strong odor and has limited applications for remaining compost. Landfilling also requires large land areas and are becoming more difficult to site within Florida due to potential groundwater impacts with the high groundwater table and sinkhole risks. Additionally, landfills produce methane, a greenhouse gas that is 25 times as potent as carbon dioxide, even with aggressive landfill gas capture systems in place.

Due to some of these limitations, the Florida legislature incentivized WTE facilities in the 1980s to encourage less reliance on landfill technologies. Due to those incentives, many facilities were built, and Florida currently has ten (10) operational WTE facilities that process MSW or RDF of which eight (8) facilities use mass-burn technologies and two (2) facilities use RDF technologies. These ten (10) facilities have the largest capacity to burn MSW of any state in the United States.

4.1 Mass-Burn/Waterwall Combustion

4.1.1 Process Description

Mass-burn/waterwall combustion is one of the most common commercially viable technologies for conversion of MSW to energy. Refuse typically does not require pre-processing before it can be combusted using this method. However, some pre-processing typically still occurs, including separation of oversized materials and removal of hazardous or potentially explosive materials. Refuse is stored in a loading bay and moved via an overhead crane or hydraulic ram onto a reciprocating or roller grate. The grate moves the refuse through a combustion furnace on the grate until combustion is complete. Combustion air in excess of stoichiometric amounts is supplied both below and above the grate. Water-filled tubes in the furnace walls are used to recover heat to produce steam and/or electricity. Generally, mass burn units range from 50 to 1,000 tons per day, and multiple units can be installed at a single facility. Bottom ash, usually about 10% of the initial volume (25% of the weight) of the incoming MSW, remains after the combustibles in the waste are burned. In addition, this process produces flue gas, which includes pollutants that must be strictly treated via air pollution control devices.[13] An example side profile of a mass-burn WTE facility is shown below.



13 https://www3.epa.gov/ttnchie1/ap42/ch02/final/c02s01.pdf

Figure 4-1. Profile Configuration of the most recently built mass-burn facility in the U.S., PBREF No. 2

Note: Image used with permission from the Solid Waste Authority of Palm Beach County

4.1.2 US and International Experience

In 2018 there were 75 operational WTE facilities within 21 states in the United States. Of these 75 facilities, 58 facilities used mass burn technologies.[14] As of 2019, there were approximately 2,179 WTE facilities in operation worldwide. Asian countries such as Japan, Taiwan, Singapore, and China have the largest number of WTE facilities in operation. Economic development and rapid urbanization in China over the past several decades have resulted in a rapid generation of over 200 million tons of MSW requiring disposal. In 2016, China had 259 WTE mass burn facilities in operation. Japan has put a heavy emphasis on WTE facilities as the country as a whole has a minimal amount of land available for landfills. Japan processes approximately 70% of its MSW in WTE facilities.[15]

Florida currently has eight (8) operating mass-burn/waterwall combustion facilities that process MSW, the most recent being the 3,000 ton-per-day Palm Beach Renewable Energy Facility No. 2 located in Palm Beach County, which entered commercial operations in 2015.

4.1.3 Suitability for Miami-Dade County

Mass-burn technologies typically have the least number of technical restrictions for waste processing. Site footprint is limited compared to other processing technologies and can be managed with additional costs. Total cost per ton of MSW processed is typically lower than most other types of processing facilities except for landfills. As the facilities typically process MSW with limited pre-processing, transfer hauling can be more efficiently routed and additional space for fuel processing is not required. Mass-burn facility sizes typically have not exceeded 3,000 tons per day of single-facility capacity in the United States due to fuel availability and flexibility for maintenance without large diversions; however, international vendors in areas like China have built single facilities as large as 5,000 tons per day. For the proposed 4,000 tons per day of MSW processing capacity as envisioned in Miami-Dade County, mass-burn technologies are both commercially available and suitable.

4.2 Modular Technologies

4.2.1 Process Description

Modular combustion units provide a smaller scale commercial option for MSW to energy conversion. They generally range from 5 to 140 tons per day, and similar to mass-burn, do not typically require refuse to be pre-processed before combustion with exceptions for oversized and hazardous or explosive materials. Two common types of modular combustors are 1) starved air or controlled air type and 2) excess air type. For starved air combustion, air is supplied to the first of two combustion chambers at sub-stoichiometric levels. This results in incomplete combustion, generating CO and organic compounds. This feeds into a secondary combustion changer

14 http://energyrecoverycouncil.org/wp-content/uploads/2019/10/ERC-2018-directory.pdf

15 https://www.mswmanagement.com/collection/article/13036128/the-current-worldwide-wte-trend

where additional air is added and combustion is completed. The process produces bottom ash and flue gas. A few newer models have acid gas/PM controls but many existing modular systems do not use air pollution controls. In the modular excess air combustor, two chambers are also used, but excess air is used in the primary chamber. Emissions from modular excess air combustors are similar to that of mass burn combustors but generally with lower NOx.[16]

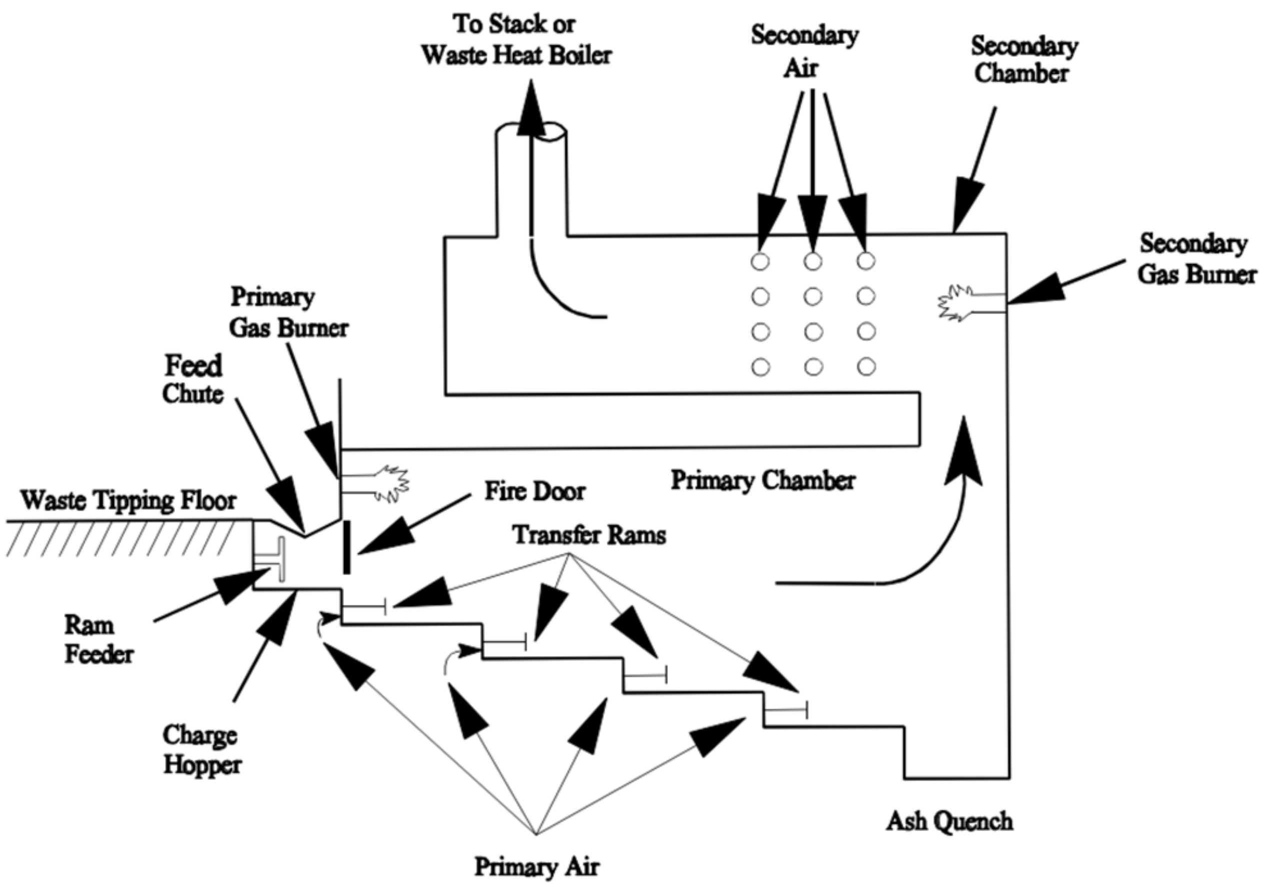


Figure 4-2. Typical Modular Starved-Air Combustor with Transfer Rams17

4.2.2 International and US Based Experience

As of 2020, there are four (4) operating modular facilities in the United States.[18] No modular facilities currently operate in Florida. As the facilities are typically small and not always captured on lists with traditional mass-burn

16 https://www3.epa.gov/ttnchie1/ap42/ch02/final/c02s01.pdf

17 https://www3.epa.gov/ttnchie1/ap42/ch02/final/c02s01.pdf

18 EPA December 2020 Assessment of Municipal Solid Waste Energy Recovery Technologies Report

and RDF technologies, it is difficult to quantify the number of facilities operating internationally. However, modular facilities are commercial and viable, within their typical size limitations.

4.2.3 Suitability for Miami-Dade County

Modular technologies typically have a very low number of technical restrictions for waste processing, but as they are sized to be mobile or constructed off-site, they are typically limited by maximum sizing. Site footprint is limited compared to other processing technologies. Total cost per ton of MSW processed is typically on par or less than traditional mass-burn WTE facilities for smaller-sized facilities, but more expensive when compared to larger facilities. As the facilities typically process MSW with limited pre-processing, transfer hauling can be more efficiently routed and additional space for fuel processing is not required. Modular WTE facility sizes typically have not exceeded 150 tons per day of single-facility capacity in the United States due restrictions on transportation for off-site construction. For the proposed 4,000 tons per day of MSW processing capacity as envisioned in Miami-Dade County, modular technologies would likely not be financially viable or easily scalable.

4.3 Refuse-derived Fuel

4.3.1 Process Description

Refuse-derived fuel combustion is another large-scale commercially viable MSW to energy technology. Refuse processed via this method usually requires pre-processing, including removal of non-combustibles and shredding of waste. This makes the feedstock more uniform for the combustion process and generally raises its heating value to improve combustion efficiency and electricity output; however, typically results in much less volume reduction than mass-burn and higher residuals remaining to be landfilled. Sometimes, RDF may be co-fired with pulverized coal. Due to these reasons, RDF facilities were typically built in the past to maximize energy output rather than maximize waste throughput. Generally, RDF combustor units can range from 320 to 1,400 tons per day.

The primary style of RDF boilers usually utilizes spreader stokers and combust RDF in a mixture of semi-suspension and traditional grate burnout. An air swept distributor blows the lighter portion of the RDF into the air which combusts in suspension while the heavier portions combust after falling on a horizontal traveling grate. Underfire air and overfire air are supplied to support mixing and completion of the combustion process. The process creates bottom ash as well as flue gas. PM levels from RDF combustion are typically double at the inlet to pollution control devices of mass-burn systems, but actual stack emissions tend to be comparable to mass-burn systems.[19]

RDF can also be combusted in a fluidized bed combustor. In this type of combustor, fluff or pelletized RDF is combusted on a turbulent bed of noncombustible materials such as limestone, sand, or silica. The combustor vessel has a gas distribution plate and underfire air windbox. The underfire air is introduced at a high flow rate, suspending/fluidizing the combustion bed. RDF, other wastes, and supplemental fuel can be injected via openings in the combustor wall. Overfire air completes the combustion process. Fluidized bed combustors utilize very

19 https://www3.epa.gov/ttnchie1/ap42/ch02/final/c02s01.pdf

uniform gas temperatures and mass compositions, which allows them to operate at lower excess air and temperature levels than mass burn systems.[20]

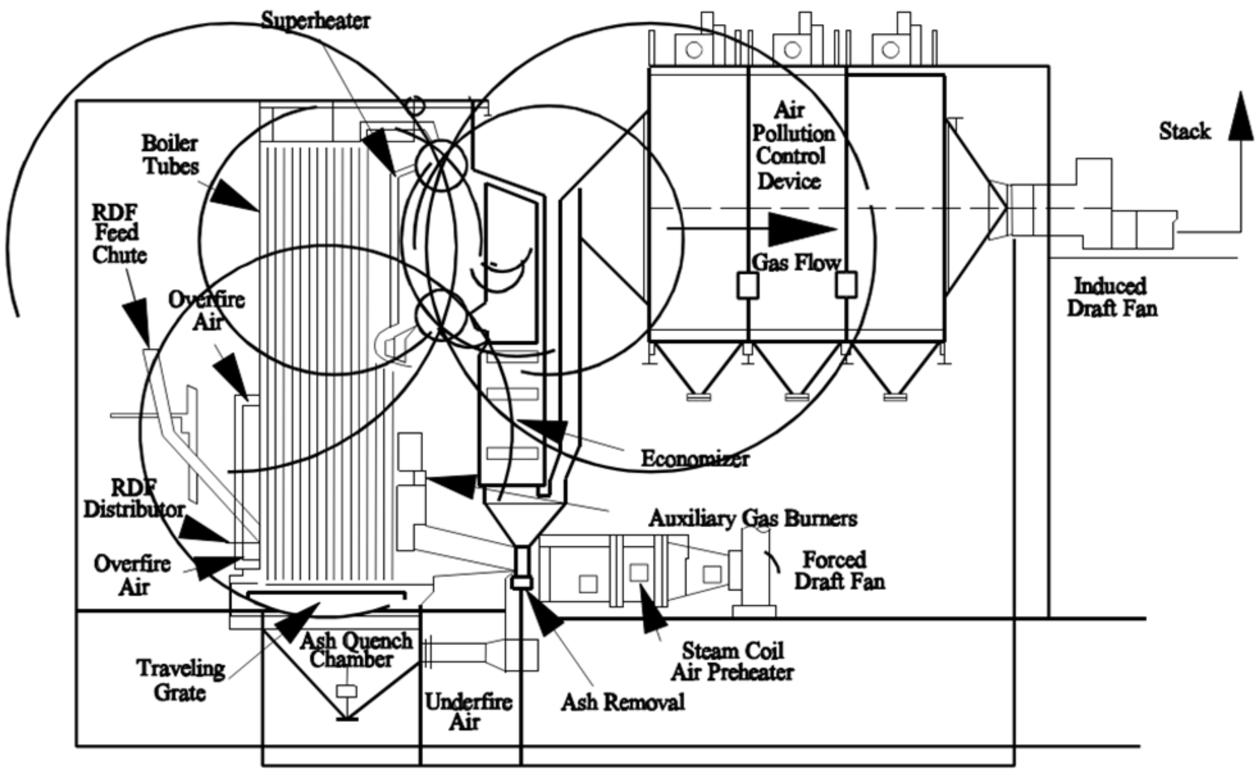


Figure 4-3. Typical RDF-Fired Spreader Stoker Boiler21

4.3.2 International and US Based Experience

As of 2020, there were currently thirteen (13) RDF WTE facilities operating in the United States.[22] There are currently two (2) of these facilities in operation in Florida, including Miami-Dade's existing RDF WTE facility. Internationally the number of RDF facilities is difficult to determine as they are often not differentiated from mass-burn style systems. However, a general estimate would be that roughly a fifth to a quarter of the almost 500 WTE facilities in Europe may be RDF facilities. These numbers are likely lower in new growth areas such as China as

20 https://www3.epa.gov/ttnchie1/ap42/ch02/final/c02s01.pdf

21 https://www3.epa.gov/ttnchie1/ap42/ch02/final/c02s01.pdf

22 EPA December 2020 Assessment of Municipal Solid Waste Energy Recovery Technologies Report

mass-burn has become the much more common choice for new facilities due to lowered MSW processing requirements and overall costs.

4.3.3 Suitability for Miami-Dade County

RDF technologies typically require a much larger site footprint in order to manage the additional processing lines to create RDF from MSW. Due to the additional processing requirements, RDF facilities typically cost more to both construct and operate than a mass-burn facility or modular facility. Due to their history of previous mixes of RDF with coal and the higher operating and construction costs, most existing RDF facilities are above 2,000 tons per day and were built to achieve maximum electrical output rather than maximum MSW volume reduction. For the proposed 4,000 tons per day of MSW processing capacity as envisioned in Miami-Dade County, RDF technologies are both commercially available and suitable, but would likely cost more to both construct and maintain than a mass-burn system and result in less volume reduction of MSW streams and more landfill requirements for residuals.

5 Emerging Waste Technologies

5.1 Gasification / Plasma Arc

Gasification is a thermochemical process that converts organic fuel or waste materials into the gaseous products of primarily carbon monoxide, hydrogen, as well as carbon dioxide and methane, collectively often referred to as a ‘Synthesis gas’ or ‘Syn Gas’. The resulting gas is considered a fuel due to the flammability and energy content and can be converted into many different liquid or gaseous fuel products, or directly combusted in a gas turbine. Unlike typical combustion that relies on a continuous supply of oxygen, gasification occurs under a limited combustion where not enough oxygen is entering the system for a complete combustion reaction. In addition, most gasification occurs at higher temperatures and pressures than a standard combustion system. These higher temperatures and pressures, along with starved-air conditions allow fuel to break apart into their constituents instead of undergoing oxidation (combustion). Those constituent gases, mostly hydrogen, methane, carbon dioxide, carbon monoxide and water vapor, can then be separated and any non-organics in the chamber are melted and form a glass-like slag typically referred to as obsidian. Once the gas is produced, it needs to be cleaned to prevent contamination issues with the fuel being developed, any water vapor is extracted, and the syn gas is cooled down. Once the syn gas is produced, there are various options on how to utilize or process it further into more valuable products. It is most commonly burned directly in internal combustion engines or combustion turbines; however, it can also be used to produce hydrogen as a natural gas alternative, or it can be used to produce methanol and other various chemicals or synthetic fuels via commercially available and typical oil/gas reformation systems.

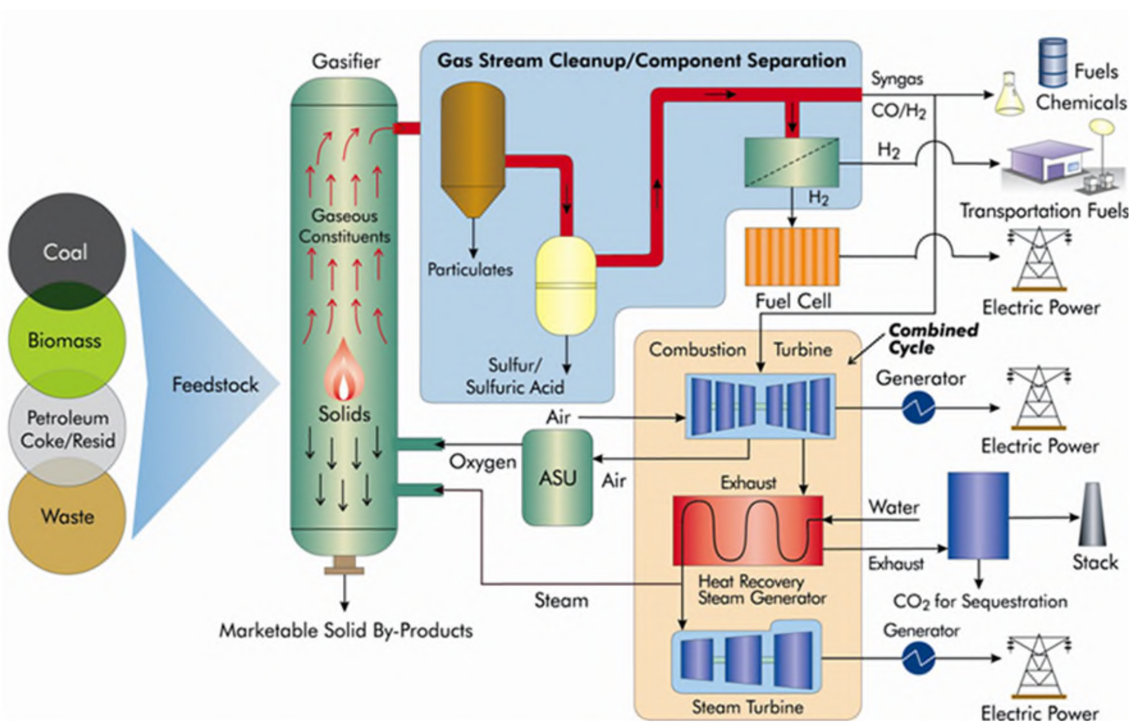


Figure 5-1. Department of Energy diagram of Gasification processes & products

There are variations in gasification system designs. Pyrolysis is considered the second stage of gasification, some facilities operate on pyrolysis to produce biochar and synthesis gas, which primarily gets condensed into a bio-oil that generally has 50-70% of the fuel value of petroleum-based oils. The bio-oil is however chemically unstable and requires refining into various fuels[23]. Another variation of gasification system design is plasma gasification. This variant relies on a plasma torch powered by an electric arc to catalyze organic matter and ionize gas into syn gas. The benefits of plasma gasification are the effective production of syn gas with minimal harmful emissions due to the extreme temperatures and a reduction in ash volume compared to traditional mass-burn technology. However, the operation of the plasma torch is energy intensive and reduces the net energy output. Several other variations of gasification technologies include moving bed, fluidized bed reactor, and entrained-flow gasifiers.

The gasifier process is chosen by the composition, quantity, and parameters of the feedstock or waste stream. Depending on the gasification process chosen, there are varying feedstock & processing restrictions. Regardless of the gasification process, a highly processed and homogeneous feedstock is required. Coal is a common feedstock for larger commercial gasifiers. There has been significant interest in co-gasifying biomass with coal to process waste. MSW can be gasified with all the main gasification processes[24], however the variations in MSW composition can influence the gasification efficiency and the caloric value of the syn gas. Higher moisture contents can also reduce the efficiency[25]. Excessive tar content from inorganic materials in MSW that creates slag can have adverse effects on the process efficiency and cause fouling of various system components such as the gas sulfur removal system. Reactor temperature can also become affected by the MSW composition. Separation of inert materials is important prior to the gasification of residual MSW, as they melt, can create excessive tar or slag which will foul the gasifier system[26]. Because of these concerns, for gasification of MSW to be successful it typically requires front-end processing, similar to RDF technologies to shred the waste, remove metals and other contaminants, and often to dry the waste to a lower moisture value. While there are plasma gasification vendors that claim they can utilize mass-burn style MSW, most technologies that Arcadis has reviewed in the past only had bench or demonstration-scale tests of waste, not full-scale tests with extremely varied waste streams.

5.1.1 International and US Based Experience

Internationally, numerous plasma gasification plants have been in operation in Japan, Korea, and Europe. The Hitachi plant in Utashinai, which was able to process 300 tons per day of MSW but had to shut down in 2013 due to increased recycling rates and limited availability of feedstock[27]. Other plasma gasification facilities in Japan, Korea, and Europe remain in operation at various smaller capacities.

US company Air Products had commissioned the world's largest capacity gasification facility, TV1 and nearly completed TV2, for the Tees Valley authority in England. The facility had sourced presorted MSW, or RDF that would fuel the facilities which were rated to have a combined capacity of 700,000 tons per year. Shortly after commissioning TV1, Air Products sold the two facilities due to design and operational challenges. The Tees

23 https://www.ars.usda.gov/northeast-area/wyndmoor-pa/eastern-regional-research-center/docs/biomass-pyrolysis-research-1/what-is-pyrolysis/

24 https://www.netl.doe.gov/research/coal/energy-systems/gasification/gasifipedia/waste

25 https://www.sciencedirect.com/science/article/pii/B9780444639929000197

26 https://www.intechopen.com/chapters/59269

27 https://www.netl.doe.gov/research/Coal/energy-systems/gasification/gasifipedia/westinghouse

Valley authority is currently in the procurement process for a new 450,000 tons per year WTE facility to process the waste of 1.5 million residents.[28]

In the United States, there have been several attempts to build large gasification technologies from a variety of vendors, but none have successfully reached commercialization at a large scale and continued operations at full load for more than a short period of time. Notable failures include the Ineos facility in Vero Beach, Florida which was intended to process both biomass and MSW, which reached preliminary commercial status but ultimately shut down and sold due to ongoing operations issues that could not be resolved. In Nevada, the Sierra biofuels facility is a 175,000-ton per year facility located in Storey County capable of creating 11 million gallons per year of renewable synthetic crude oil, or "Syncrude," that will be processed by Marathon Petroleum into transportation fuel. The facility is owned by Fulcrum BioEnergy, Inc. and works on modern gasification techniques with a proprietary Fischer-Tropsch (FT) fuel process[29]. At the time of this report, the Fulcrum BioEnergy facility has publicly announced successful production of syn gas during commissioning, but is not yet operating at a full commercial capacity to create transportation fuel.

In Canada, the Enerkem/ Suncor Alberta Biofuels facility is the first commercial scale biorefinery in North America. The 100,000 tons per year facility produces a syngas platform capable of converting MSW to methanol, ethanol, drop-in fuels and circular chemicals, such as acetic acid, acrylic acid, and olefins. The facility uses a low oxygen gasifier and other proprietary processes to produce its fuels and chemicals[30]. However, while it has been publicly announced to have achieved commercial operation and is producing fuel, the facility has had multiple reports of shutdowns and re-designs to address ongoing operations and capacity issues and its full commercial status when compared to design is not known at this time.

5.1.2 Suitability for Miami-Dade County

Gasification has some advantages over combustion for emissions control, as gasifiers produce synthesis gas at higher temperatures and pressures than in typical combustion. These higher temperatures and pressures allow for easier removal of SOx, NOx & CO2 from emissions. Once the synthesis gas is produced from the gasification chamber, it needs to be cooled and cleaned to prevent fouling. Particulates are filtered out using a baghouse or cyclone, and the gas may need to be scrubbed for acids due to potential sulfur content. Because the syn gas Is directly captured during the gasification process, there is reduced emissions when compared with traditional WTE technologies. However, if the syn gas is burned directly (unless it is converted or cleaned to pure hydrogen) to generate power such as via a combustion engine or gas turbine, there could be criteria pollutants emitted.

Aside from the potential various products and benefits of gasification, when considering gasification as a primary method of processing MSW in Miami-Dade, there are some problems that require consideration. The major limitation of the gasification technology to Miami Dade County, would be the limited daily processing tonnage capacity. Existing facilities for plasma gasification, which appear to be the ideal for MSW, all have very low capacities and have reported higher operating costs. Most facilities in operation internationally are under 100 tons per day, which would not be an appropriate scale-up to the 4,000 tons per day of processing capacity required by Miami-Dade County. For non-plasma systems a significant challenge remains for the design and process optimization, as the thermochemical reactions must be optimized under the varying feedstock compositions and feedstock processing requirements would increase the cost and reduce the throughput of a gasification facility.

28 https://www.letsrecycle.com/news/air-products-to-halt-tees-valley-gasification-project/

29 https://fulcrum-bioenergy.com/facilities/

30 https://www.oilandgasiq.com/decarbonization/interviews/from-our-archives-turning-garbage-to-ethanol-to-reduce-albertas-co2-footprint

There are no large-scale traditional gasification technologies utilizing MSW that have stayed in operation over 10 years or not reported significant processing and maintenance issues that caused cost increases.

5.2 Anaerobic Digestion

In anaerobic digestion for MSW, the feedstock input would be pre-sorted organic MSW such as food and yard waste which gets fed into water tanks and formed into a wet slurry via conveyors, pumps, and mechanized agitation. Insoluble inorganics such as glass, plastics, and metals are discharged for separate processing or disposal. The resulting slurry, or "black water", has a high organic content that is broken down and consumed by microorganisms such as methanogens, which generate methane in environments of no oxygen. The slurry stream is sent to be processed by these organisms in a series of sealed chambers/digesters that are designed to remain at the optimum conditions for anaerobic digestion. The slurry remains in the chambers for a determined residence time to optimize the production of gas. The resulting biogas that has been produced is rich in methane and other organic gases that are captured and can be used for electricity generation, sold to a local gas utility, or used as fuel. The remaining organic solids from the digestion can be used as compost and liquids may be used as fertilizer.

Anaerobic Digestion is a common type of organic waste facility used in the processing of sewage sludge at water resource recovery facilities which is considered liquid waste digestion. Also commonly used to process manure at large livestock facilities, and in the processing of food waste. A 2021 EPA report covering 209 facilities shows the top feedstock sources for anaerobic digestion to be Fats, Oils and Greases (FOG), and food waste[31]. Some digesters are designed to process one specific type of feedstock such as sludge in a water resource recovery facility, while others that can digest varying compositions of organic waste, such as is found in MSW, are called co-digestion. The biogas created can be further processed into renewable natural gas (RNG) with investment into a biofuel processing facility.

Anaerobic digesters have been increasingly used to combat the emissions issue of food waste by diverting it from landfills, where it decomposes and creates methane, a greenhouse gas with 25 times greater global warming potential than carbon dioxide[32]. Biogas production creates additional income and can reduce the overall costs of operating waste handling facilities if organics can be presorted from MSW. Figure 5-2 below shows an EPA process diagram of anaerobic digestion. The organic feedstock becomes processed and creates the two coproducts of solid compost and a liquid concentrate fertilizer which may be sold for agricultural purposes. It is critical that the presorting is efficient at removing nonorganic waste to prevent contamination and ensure quality coproducts that can be sold.

31 https://www.epa.gov/sites/default/files/2021-02/documents/2021_final_ad_report_feb_2_with_links.pdf

32 https://www.epa.gov/ghgemissions/overview-greenhouse-gases

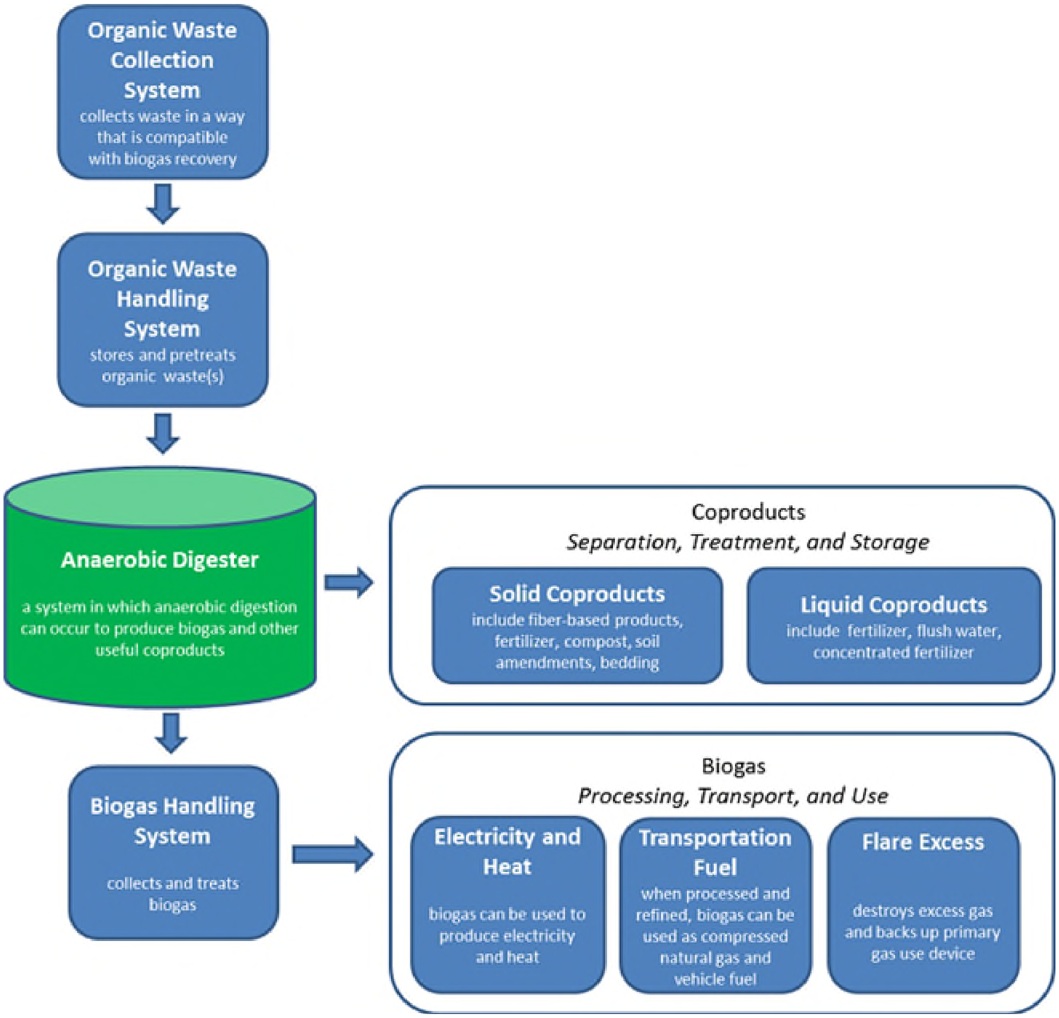


Figure 5-2. EPA Diagram of Anaerobic Digestion Process

Air pollution control (APC) is an important consideration to meet air quality permitting requirements for any waste processing facility, however, anaerobic digestion plants capture most gases produced when the facility collects biogas. Emission sources for this facility are primarily if combustion of the biogas is commenced such as with an internal combustion engine to generate electricity at the facility, thus requiring APC devices to ensure the emissions meet air quality permitting requirements. Potential APC devices required would include baghouses for particulates, scrubbers for SO_2, oxidation catalysts and/or selective catalytic reduction for various other air pollutants. A flare may also be an additional source of emissions when the facility has reached capacity of gas storage and is required to burn any excess that is produced.

As the process of anaerobic digestion is biologically driven, it requires time for the microorganisms to start up the digestion process and manage the organic waste. Due to the processing time requirement, anaerobic digesters require large chambers and processing vessels that requires a high level of investment & increased land use. Contamination from non-organics, and hazardous materials in MSW can have a detrimental inhibition on the digestion process or biogas production, therefore it is important to have an efficient sorting system.

5.2.1 International and US Based Experience

A recent EPA report showed 33 operating anaerobic digester facilities in the US as of 2020. Almost all of the facilities are processing waste streams where organics were separated from MSW through either source-side or mechanical processing means prior to supply to the facility (not directly coupled with the facility).

While the facilities can vary in size, they are easily scalable with sufficient available organic feedstock and land availability for the digesters. The city of Surrey, Canada recently built a biofuel facility that processes organic solid waste through anaerobic digestion. The facility handles approximately 115,000 tons of organic waste per year and converts its biogas into RNG that is used to power the city's fleet of natural gas-powered vehicles. The facility also markets the residual solids from digestion as compost for additional income[33].

5.2.2 Suitability for Miami-Dade County

When considering anaerobic digestion as a primary method of processing MSW in Miami-Dade, there are some problems that should be considered. Due to the processing time, biological sensitivity to contaminants and large land footprint, anaerobic digestion is best suited for areas with a smaller population, as the daily processing capacity in tons are significantly lower when compared to more commonly adopted technologies such as waste to energy facilities that can handle large daily tonnage capacities of incoming MSW. The Surrey biofuel facility is ideal choice for the city of Surrey, as there are lower amounts of solid waste generated due to a smaller population of 568,322 [34] compared to a large metropolitan area of Miami-Dade County with a population of 2,662,777 [35] and high tourism. Another concern is how the separation of organics from nonorganic materials can be successfully implemented at either collection or preprocessing with high efficiency. Contamination of non-organics and hazardous materials in MSW can have a detrimental inhibition on the digestion process or biogas production. Contamination would also lower the value of the compost and liquid concentrate fertilizer coproducts that may have given additional revenue. This required separation would still require a more traditional processing or disposal facility (i.e., WTE or landfilling) for the remaining inorganic materials. Ideally, if Miami-Dade built an organics separation facility coupled with anaerobic digestion, it would be a way to divert a portion of the MSW stream; however, it would likely be best used as a hedge against future MSW increases and removing necessity of building additional WTE or landfills, not as a primary disposal or processing technology.

5.3 Mechanical Biological Treatment / Solid Recovered Fuel Technologies

Mechanical Biological Treatment (MBT) is a combined approach to solid waste management that has both mechanical and biological treatment phases separately processed to ultimately produce a pelletized solid fuel. The mechanical stage comprises of automated mechanical sorting equipment such as via conveyors, magnets, trommels, shredders and eddy current separators to process combustible materials, while the biological treatment stage of MBT could involve anaerobic digestion, composting or bio drying. Use of anaerobic digestion would

33 https://www.surrey.ca/services-payments/waste-collection/surrey-biofuel-facility/about-surrey-biofuel

34 https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/details/page.cfm?Lang=E&SearchText=Surrey&DGUIDlist=2021A00055915004&GENDERlist=1&STATISTIClist=1&HEADERlist=0

35 https://www.census.gov/quickfacts/fact/table/miamidadecountyflorida/POP060210

reduce the organics content, stabilize the waste and produce biogas for collection, bio drying serves to stabilize the organics by reducing the moisture, where later they are combined with the other processed waste and formed into SRF pellets. This method involves the separation of waste without requiring the generator to separate the MSW at waste collection points. The biological stage is effective at processing the organics in MSW and producing products like biogas and compost. As a result of the mechanical and biological separation and processing, both fractions of waste are combined, shredded, and converted into pelletized solid recovered fuel (SRF). These separated components of MSW are dried, shredded and blended to meet fuel specifications and quality standards. An additional product of MBT is a compost-like output which usually is of low value due to concerns of contamination[36].

The benefits of MBT and processing MSW into SRF, is an improved quality pelletized feedstock fuel that can serve as a renewable substitute for coal or other solid fossil fuels. An additional benefit is the reduction in greenhouse gas emissions from the displacement of fossil fuels. Some European MBT facilities have agreements with cement manufacturers to provide SRF as a replacement for coal or petroleum coke to fire up cement kilns and coal power plants. Some concerns regarding the usage of SRF was the fuel specifications. Issues such as fouling, increased mercury emissions and ash production, and increased oxidation & corrosion of equipment.[37]

5.3.1 International and US Based Experience

MBT has higher adoption in Europe, where it is widely used for processing MSW. One study of six European facilities concluded that a MBT plant must have a very efficient sorting and recyclables recovery line with sufficient gate fees. It also found that including a stream to recover fuel materials for power plant or cement plant use can increase revenue, landfill diversion, and reduce greenhouse gas emissions. In this study, the six European facilities processed between 16,500 to 350,000 tons of MSW per year.[38]

MBT has not received wide adoption in the US, however there are numerous facilities in Europe to study. Facility capacities for MBT are typically in range from 25,000 – 200,000 tons per year.[39] In 2017, Entsorga West Virginia LLC began operation on the first MBT facility built in the U.S. The facility had a capacity of 110,000 tons per year, and produced SRF for the Essroc cement plant nearby to heat up the Portland cement kiln.[40] Just recently after 3 years of operation, the facility closed due to a reported intellectual property lawsuit. Entsorga states the shutdown is temporary.[41]

5.3.2 Suitability for Miami-Dade County

When considering MBT/SRF technologies as a primary method of processing MSW in Miami-Dade, there are some problems that should be considered. The biggest limitation to this technology regarding Miami-Dade's needs would be that the tonnage capacity for existing facilities is not nearly enough to handle the amount of MSW generated within the county. Approximately 200,000 tons per year is the higher end on the range of typical existing MBT facilities. Another consideration is analyzing the existing MSW composition and determining what

36 https://www.swim-h2020.eu/wp-content/uploads/2018/03/3a-Part2-Ben-Amor-Long-Term-Solutions-for-Solid-Waste-Management.pdf

37 https://www.researchgate.net/publication/281905251_MBT-derived_SRF_State-of-the-art_in_Europe_Will_Quality_Management_Deliver

38 https://www.sciencedirect.com/science/article/abs/pii/S0956053X22000253

39 https://www.ciwem.org/assets/pdf/Policy/Policy%20Position%20Statement/Mechanical-biological-treatment-of-waste.pdf

40 https://renovareenv.com/entsorgawv/

41 https://morgancountyusa.org/?p=5451

the SRF fuel specifications need to be to sell the product. Additionally, the facility would need efficient removal of contaminants and hazardous materials prior to mechanical and biological separation, especially if bio drying will be utilized. Additionally, as MBT/SRF technology is primarily a processing, it still needs a partner to use the product as fuel or a facility to burn the fuel created. If coupled with RDF or other combustion technologies, this process would be much more expensive than a technology such as mass-burn.

6 Recent Waste Processing Technology Procurements and Facility Expansions

As previously stated, the US currently uses 73 WTE facilities to combust MSW and recover energy. While several have expanded to manage additional waste, the last new facility opened was in West Palm Beach, Florida in 2015[42]. Since that time, no new greenfield commercial plant has been implemented in the US. The following sections describe select initiatives that occurred in the last ten (10) years related to evaluating and choosing waste processing technologies – WTE and others – to handle significant waste streams in the future for certain jurisdictions.

6.1 Procurements

6.1.1 St. Lucie County, FL

In May 2006, the Board of County Commissioners, St. Lucie County, Florida solicited offers to design, permit, finance, construct, and operate a Plasma Arc Gasification Facility to process MSW for St. Lucie County. There were two respondents to the RFQ: Alternative Resources, Inc. and Geoplasma, LLC that resulted in Geoplasma LLC as the highest ranking respondent.[43] The developer planned to process 3,000 TPD, generating 120 megawatts of electricity. The plant was to cost over $425 million.[44] The size of the facility was reduced to 600 TPD with an estimated export of 18 MW of electricity. FDEP issued a final air permit in July 2010.[45]

In 2012, St. Lucie County terminated the agreement with Geoplasma. The St. Lucie County solid waste division director stated that Geoplasma could not finance the project due to inability to obtain a technology guaranty from the technology owner, Westinghouse Plasma. The County also could not commit to deliver Fort Pierce, FL MSW to the proposed plant, leaving only the County and Port St. Lucie MSW for processing throughput[46].

In April 2012, St. Lucie County authorized issuance of a Request for Qualifications (RFQ) from firms to design, permit, finance and operate a thermal conversion facility for the processing MSW. Six firms responded with Covanta Energy Corporation (Covanta) ranked highest and Jacoby Synergy Renewables (JSE) ranked second highest. Negotiations with Covanta and the County could not be completed due to the processing fee within four years would be substantially higher than the St. Lucie County's processing fee. In 2013, the County entered into negotiations with JSE but the two parties were also unable to agree to a revised JSE proposal.

In 2014, St. Lucie County issued an RFQ to utilize a thermal conversion facility to process MSW. Of 331 companies notified, 27 copies of the RFQ were issued and six (6) proposals were received. In 2015, St. Lucie County approved entering into contract with Green3Power St. Lucie, LLC (G3P) to build and operate a gasification facility at the St. Lucie County site.[47] Available literature related to the proposed facility indicated that

42 https://www.epa.gov/smm/energy-recovery-combustion-municipal-solid-waste-msw

43 Approval of Short-Listed Firms for RFQ No. 14-057 - Utilization of a Conversion Facility to Process Municipal Solid Waste for St. Lucie County - St Lucie County, Florida (iqm2.com)

44 Company plans $425 million gasification plant to recycle trash (starnewsonline.com)

45 GeoPlasma-St. Lucie - Energy Resources Group, Inc. (energyresourcesgrp.com)

46 https://www.floridatrend.com/article/14356/trashed-plan-to-use-plasma-technology-for-garbage-disposal

47 Lease and Contract with Green3Power St. Lucie, LLC - Development of a Gasification Facility to Process Municipal Solid Waste for St. Lucie County - St Lucie County, Florida (iqm2.com)

in 2018 St. Lucie County is exploring alternative waste conversion technologies. No further documentation could be located regarding the implementation of this facility.

6.1.2 New York City, NY

In 2012, a request for proposals (RFP) for a pilot program to process 450 tons of waste per day (capable of doubling capacity if successful) was issued. The RFP called for constructing a WTE facility near or within New York City. The pilot program implementation process was eventually stopped. However, as of 2019, New York City sends approximately 25% of collected waste to existing WTE facilities outside of New York City.

6.1.3 Hartford, CT

In November 2015, the Connecticut (CT) Department of Energy and Environmental Protection (CTDEEP) issued the Phase 1 RFP for financing, design, construction, operation and maintenance of a Waste Recycling and Disposal Project to qualify firms and technologies to re-develop the CT Solid Waste System Project (CSWSP). The CSWSP includes recycling facility, four transfer stations, and the 2,850 tpd RDF facility known as the Connecticut Solid Waste System Resource Recovery Facility (CSWS RRF) in Hartford, CT. The CSWS RRF includes a Waste Processing Facility (WPF) and Power Block Facility (PBF). Technologies submitted included:

- Mixed waste processing facilities
- Anaerobic digestion
- Composting
- Gasification (pyrolysis, plasma arc, etc.)
- Other conversion technologies to create renewable fuels, chemicals, electricity or other usable products

CT DEEP selected three firms to receive the Phase 2 RFP:

- Covanta Energy, LLC – source separated organics processing through anaerobic digestion and haul to Covanta WTE facilities with potential expansion of existing Covanta Bristol, CT WTE facility.
- Mustang Renewables Power Ventures, LLC – organics processing through composting and anaerobic digestion; mixed waste processing to remove recyclables and deliver processed engineered fuel (PEF) to cement kilns.
- Sacyr Rooney Recovery Team, LLC. (Sacyr Rooney or SRRT) – refurbish existing PBF and construct new sorting lines at the WPF to extract recyclables and organics; organics processed through enclosed, aerobic composting and anaerobic digestion.

In December 2017, CT DEEP selected Sacyr Rooney to modernize the CSWS RRF and directed the Materials Innovation Recycling Authority (MIRA) to enter into agreement with Sacyr Rooney. MIRA and SRRT entered into a memorandum of understanding to further negotiations in July 2019. In July 2020, CT DEEP rejected the $330M refurbishment of the existing facility. At this time, the CSWS RRF is planning to be closed between mid-2022 to 2023 and waste will be transported for disposal in other resource recovery facilities or out-of-state landfills.

6.1.4 Solid Waste Authority of Palm Beach County, Florida

In December 2008, the Solid Waste Authority of Palm Beach County, Fl (SWA) issued an RFQ to identify qualified firms to design, build and operate a new waste-to- energy facility for the County. The SWA was seeking mass-burn technology that demonstrated success in the efficient and feasible conversion of MSW into marketable steam, thermal energy, fuel and electricity. The SWA Governing Board selected three firms that responded to the RFQ to receive a Request for Proposals (RFP): (1) Babcock and Wilcox (B&W); (2) Covanta Energy; and (3) Wheelabrator Technologies to receive the Request for Proposals (RFP). The RFP first RFP was released in February 2010 after receipt of comments on the draft RFP from qualified firms. Because the new WTE facility is to model the best practices of the industry, SWA developed a Conceptual Planning Report and an Aesthetic Conceptual Design along with the draft RFP to establish SWA's objectives with respect to achieving the highest standards of sustainable "green" design. The first RFP was cancelled in August 2010 to address additional permitting requirements from the FDEP to incorporate selective catalytic reduction (SCR) technology for enhanced NOx emissions control. The second RFP was issued in September 2010. Proposals were received in December 2010. SWA entered into agreement with the joint venture of KBR and B&W in April 2011. The new 3,000 tpd Palm Beach Renewable Energy Facility No. 2 (PBREF No. 2) WTE facility is located on the SWA Energy Park Campus and achieved commercial operations in July 2015.

6.2 Florida Waste-to-Energy Facility Expansions

Since the 2015 start of operations for the SWA of Palm Beach County PBREF No. 2, there have not been any new waste-to-energy facilities built in the United States. We are aware of other communities that are further investigating innovative waste processing technologies or building new waste-to-energy capacity in areas outside of Florida. For example, the Port of Seattle, WA in conjunction with King County, WA commenced a study in 2022 to review the state of the industry in converting the MSW stream or portion of the MSW stream into sustainable aviation fuel.

However, the majority of the efforts related to waste processing facilities have been focused in several communities with existing waste-to-energy facilities that have or are planning to expand their existing WTE facilities. Other than the 2012 completion of the mass-burn expansion of Covanta's H-Power facility in Honolulu, HI and the 2010 completion of permitting for the planned expansion of the existing York County, PA mass-burn combustion facility, the completed WTE expansions have primarily focused on the Florida facilities.

The following represents a summary of the status of completed expansions to existing waste-to-energy facilities in Florida:

Hillsborough County, FL

In 2007, Hillsborough County sole-sourced to Covanta for a new 600-TPD line to add to the existing 1200-TPD facility which consists of three operating 400-TPD lines. There was no RFP issued for the expansion that was completed in 2009. The expansion increased the facility capacity from 1,200 to 1,800 TPD and also included an additional turbine generator. The electricity that is produced is used to power residential homes as well as the adjacent wastewater treatment plant. In 2022, Hillsborough County noted plans in a recent capital improvement project planning document to build a new facility with at least 1,950 tpd processing capacity.[48]

Lee County, FL

In 2006, Lee County contracted with Covanta to add a third line with a 636-TPD capacity to the existing 1200 TPD facility. The expansion continued to use the same Martin technology. The Lee County Solid Waste Division finished its expansion project in the late summer of 2007. The facility processes more than 622,000 tons of waste

48 FY22 - FY27 Adopted Capital Improvement Programs (CIP) (hillsboroughcounty.org)

per year and produces 57 MW of electricity. In February 2022, Lee County and Covanta reached an agreement to extend their public-private partnership of the facility through 2031. The agreement also included an optional four-year extension[49].

Pasco County, FL

In February 2022, Pasco County filed with the FDEP the Unit 4 supplemental application through the Florida Power Plant Siting Act to expand their existing WTE facility with the addition of a fourth unit of 475 tpd processing capacity.[50] Prior to the submission of the permit application, Covanta was selected to design and build the expansion and continued operation of the existing facility and the expanded facility after completion.[51]

49 https://www.covanta.com/news/press-releases/covanta-lee-county-fla.-extend-waste-to-energy-partnership-to-2031?hsLang=en

50 Pasco County Resource Recovery Facility Expansion - Unit 4 Supplemental Application | Florida Department of Environmental Protection

51 Pasco takes first step to expand its trash-to-energy incinerator (tampabay.com)

7 Summary and Conclusions

7.1 Summary and Comparison for Use at Miami-Dade

The table below provides a limited break-down of technology types, including some not specifically reviewed in this report to assist in a qualitative understanding of the variety of technology types that may be available. It is important to note that within each of these technologies are often specific proprietary equipment and operating practices that vary all of the overall specifics, so references provided are for generic averages based on Arcadis' experience in the industry and do not reflect a specific vendor or design for each technology.

Table 7-1. Technology Comparison Table

Technology	Waste Input	Facility Sizing[1]	Facility Cost vs Mass-Burn[2]	Miami-Dade Implementation Recommendations	Additional Notes
Landfill	Pre- or Post-Recycled MSW, Residue	Unlimited capacity, but limited by space to site	Lower than mass-burn cost/ton	For MSW and residue disposal after diversion and processing technologies.	Technology not analyzed in this report.
Composting	Organics	Unlimited capacity, but limited by space to site and source separation or mechanical separation volumes	Greater than mass-burn cost/ton	For organics diversion before processing and disposal technologies. Not a primary disposal center.	Technology not analyzed in this report.
Recycling	Source Separated Recyclables	Limited by source separation or mechanical separation volumes	Greater than mass-burn cost/ton	For waste diversion before processing and disposal technologies. Not a primary disposal center.	Technology not analyzed in this report.
Mass-Burn WTE	Post-Recycled MSW	Viable from 0 to 5,000 tons per day in a single facility	N/A	Viable as a primary processing and disposal technology for 4,000 tons per day capacity.	
Modular WTE	Post-Recycled MSW	Viable from 0 to 200 tons per day	Greater than mass-burn cost/ton	Not viable for primary processing and disposal at 4,000 tons per day capacity.	Scale-up not feasible due to cost.

Technology	Waste Input	Facility Sizing[1]	Facility Cost vs Mass-Burn[2]	Miami-Dade Implementation Recommendations	Additional Notes
RDF WTE	Post-Recycled, Processed MSW	Viable from 0 to 5,000+ tons per day in a single facility	Greater than mass-burn cost/ton	Viable as a primary processing and disposal technology for 4,000 tons per day capacity.	Requires larger site footprint and larger residuals stream than mass-burn.
Gasification	Post-Recycled, Processed MSW	Viable from 0 to 500 tons per day	Greater than mass-burn cost/ton	Not currently viable for primary processing and disposal at 4,000 tons per day capacity.	Larger size units not commercially proven. Further scale-up may not be feasible due to costs. Pre-processing for viable units could be extensive and costly.
Anaerobic Digestion	Contaminated Organics	Unlimited capacity, but limited by space to site and source separation or mechanical separation volumes	Less than mass-burn cost/ton	Not viable for primary processing and disposal at 4,000 tons per day capacity. Better use as waste diversion before processing and disposal technologies.	Site area required and separation may limit ability to use. Not commercially proven at higher scales, but most technology is modular.
MBT/SRF	Post-Recycled, Processed MSW	Unlimited capacity	Greater than mass-burn cost/ton	Not a true disposal site as its primary use is for pre-processing and fuel preparation. Not viable for primary processing and disposal at 4,000 tons per day capacity.	Requires extensive pre-processing and would still need a disposal site for fuel. Could be coupled with gasification to increase viability, but at high cost.

Notes:

1. Sizing roughly estimated based on existing large-scale commercial technology availability.
2. Costs roughly compared to mass-burn technology. Each technology price could vary considerably depending on specific technology and vendor, so specific quantifiable numbers or ranges are not provided.

7.2 Conclusions

Based on the review of the technologies noted in this report, the largest limiting factor for waste processing and disposal technology viability at a 4,000 ton-per-day size is the commercial availability of scaled up units. Mass-burn technology and RDF technology are the only large-scale volume reduction technologies that are technically feasible for the sizing required for the County. While both could be utilized to meet the throughput criteria, mass-burn would be considerably less expensive and take up a smaller site footprint than RDF. In addition to not being commercially viable at the required throughput capacity, the remaining available technologies (except landfilling) would all require more available land area and would be at a greater cost point than mass-burn or RDF technologies.

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